NEW REQUIREMENTS TO THE EMERGENCY EXITS OF BUSES

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ABSTACT

Based on certain assumptions, the requirements of emergency exits on buses and coaches are specified in ECE Regulation No.107. Different accident situations, real accidents proved that some of the original assumptions are not valid, so it is necessary to reformulate them. Accident statistics – containing some hundreds bus accidents – and in depth accident analysis were studied, concentrating on the evacuation of buses and the rescue possibilities of the bus occupants. Certain results and conclusions of evacuation tests are also considered which show the capabilities and limitations of different groups of passengers (men-women, young or elderly people, etc.) when evacuating the bus through different kind of emergency exits. The new assumptions to specify the required number and location of emergency exits of buses are based on the following perception: the usability of the individual emergency exits are different in different bus categories (e.g. low floor city bus, high-decker tourist coach, etc.) or even in one category (lower or upper level of a double-decker bus) and also in different accident situations (e.g. frontal collision, rollover, fire, etc.) The next step is to specify the "usability" in technical, measurable terms. The paper proposes four aspects, shortly: to open the exit, to creep through the exit, to step/jump down from the bus and the possibility of the continuous use of the exit. Some possible measures are proposed to these aspects. On the basis of these aspects, all the emergency exits may be qualified (good, acceptable, poor, not usable) in every bus categories and every accident situation. Finally the required number of emergency exits (how many good, acceptable exit) could be specified which shall be provided for the occupants in every essential accident situation.

INTRODUCTION

In the case of an accident situation the passengers of a bus have to leave the vehicle as quickly as possible. To do that they use every kind of exit available for the evacuation. The following exits were considered to serve as emergency exits (EE): service door; emergency door; door of the driver's cab; side window and rear window designated as emergency window; escape hatch and rear wall door in case of small buses. The existing requirements for the bus EE-s are summarized in the UN-ECE Regulation 107, (R.107) among a lot of other general safety requirements of buses. The EE's requirements are grouped as follows:

a) required number of EE-s
b) their location and distribution
c) the required minimum dimensions
d) required access to EE-s
e) technical requirements of their operation.

These requirements are in force since 30 years and during this period only a few, small corrections were made to improve them for better understanding. But during this period a lot of experiences were collected about the usability of different EE-s and some very serious accidents – fire in the bus, many injured passengers on board, panic among the passengers, etc. when the passengers could not evacuate the bus – called the attention to the problems of the existing regulation. The need for improving the regulation has been raised in different working and expert groups of the UN-ECE organization in Geneva. This paper tries to contribute to the discussion of this problem, concentrating on the subject groups "a" and "b" mentioned above.

PRINCIPLES OF THE EXISTING REQUIREMENTS

When working on the requirements of EE-s in the bus regulation – 30 years ago – certain assumptions were used as starting points. (It has to be mentioned: at that time the experts did not have too many information, experience on that field) Of course these assumptions are not mentioned in the regulation, but their consequences may be recognized:

- only that accident situation was considered when the bus is standing on its wheel.
- the number of EE-s shall be proportional somehow to the passenger capacity of the bus
- every separated compartment – passenger and driver compartment – shall have EE. (This requirement has special importance in articulated and double deck buses)
- the number of EE-s shall be closely the same on the two sides of the bus, as well as in the front and rear half of the vehicle.
- all kind of EE-s have the same usability, they are equivalent to each other in all emergency situations.

- a certain EE type (e.g. side window) has the same usability in all bus categories (e.g. mini-bus or the upper part of a double deck bus)
- a certain EE type (e.g. escape hatch) has the same usability in every major accident situations (e.g. the bus is standing on its wheel or on its roof)

Figure 1. General collapse of the superstructure in rollover

At the beginning it was not considered, but later it became evident that the EE-s can be used only if the bodywork of the bus – at least in the surroundings of the EE – is not strongly damaged. The large scale structural deformations generally prevent to access, to operate and use the EE. Figure 1. gives examples about the total collapse of the superstructure in rollover accidents. These pictures prove that in these cases it is meaningless to talk about EE-s. Figure 2. shows examples when only one, or just a few EE-s can not be used because of strong, local structural deformations.

Figure 2. Local large-scale deformation of the bodywork

ACCIDENT SITUATIONS TO BE CONSIDERED

When improving the requirements of EE-s, some of the original principles mentioned above should be reconsidered. One of the major issues is the list of the major accident situations to be considered, in which the EE-s can help, must help in the evacuation of the bus. These are:

- rollover, considering the possible major situations after the accident (until one complete rotation),
- front impact, considering the total or partial impacts, too,
- side impacts, considering both sides and only heavy vehicles as impacting partner
- rear impact, considering heavy vehicles when impacting the full rear wall.
- fire in the bus, considering different locations of fire initiation
- bus in shallow water (not completely sunk)
- combined accidents (the combination of the above said accidents)
- special accidents.

Two of these accident situations need particular attention. The rollover is the most complex accident. More final bus positions may occur, but at least four basic situations shall be considered. The bus stops on its one side, or on the other one, may be on its roof or on its wheels. This last situation means that the rollover accident contains the basic evacuation situation, too, when the bus is just standing on its wheels.

The other important accident situation is the fire. The fire brings a very important, essential parameter into the evacuation process: the time limitation. The fire generates smoke, poisoning gases and heat which can block the passengers in the evacuation. It is interesting to mention that sometimes the fire is the consequence of a rollover or a frontal collision (combined accident situation). In a rollover statistics containing 383 bus rollover accidents, 12 times the rollover was followed by a fire and the bus completely burned out. Among 256 frontal collisions it happened 14 times. These are very severe accidents with extremely high mortality and casualty rate.

Figure 3. Fire tests with complete bus type IK255

Fire tests were carried out in Hungary with three complete buses (type IK 255 and IK 415) simulating five fire sources. Figure 3. shows one test when the whole fire propagation process was observed and studied with the measurement of temperature and some poisoning gas concentration increasing. [1] The source of fire was in the closed box of the heating device, under the floor. The measured values (CO, HCl, HCN gas concentrations; temperatures T_{far} far from the fire source and T_c close to that) are presented on Figure 4. Without detailed discussion of the test results it may be said that from the first possible observation of the fire, the available time for evacuation was in the range of 200-300 sec. The smoke density was not measured, but visually detected by filming it was developed very rapidly. The critical values of gas concentrations are marked by a horizontal line on the left side of the diagram. The life danger is mainly due to the gas and smoke concentration and less to the high temperature.

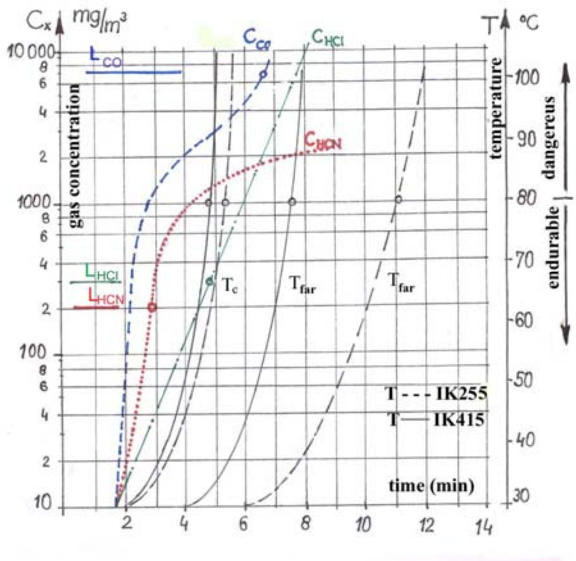


Figure 4. Increasing of temperature and poisoning gas concentrations in the bus fire.

THE USABILITY OF DIFFERENT EMERGENCY EXITS

Figure 5. Usability of side emergency window

The assumption that the usability of a certain type of EE is the same in every bus categories is not true. Figure 5. shows the usability of the side emergency windows in case of double deck (DD) bus comparing the upper and lower level passenger compartment (after a frontal collision) and also the situation on a high (but single) deck (HD) tourist coach. The side emergency window is a very useful exit in the case of the lower level of a DD bus or on low floor buses, but they cannot be used in the case of the upper level of a DD bus or on a HD coach.

The assumption that the usability of a certain type of EE is the same in different accident situation is also not true. Figure 6. shows some examples. The escape hatches are absolutely not usable when the bus is laying on its roof. The side emergency windows are well usable (on both side) in this situation in large buses, but they are almost useless in small buses. For small buses the rear wall door is very useful in this case.

Figure 6. Usability of escape hatches (?)

The assumption that all kind of EE-s have the same usability (they are equivalent and replaceable) is also not valid. Figure 7. gives a very clear argument considering and comparing all the possible (and required) EE-s on DD coaches, e.g. side windows, escape hatches, rear wall window, service door and the door of the driver compartment.

There is one important question to be raised. In the existing regulation the windscreen is not considered as possible EE. The reason of that is that the windscreens are made from laminated glass and therefore it is not breakable. But in the last few years a very effective new technology has been developed and already used by the firemen: to cut the laminated glass with a small (4 kg of mass) electric rescue saw. It could be placed in the driver's compartment. (similarly to the fire extinguisher) and if necessary, used by the driver. Figure 8. shows examples, when this device was used after an accident by the fire brigade. It can be seen easily that the windscreen is one of the best, most usable EE in many accident situation, so in the future it should be considered.

Figure 7. Different emergency exits do not have the same usability

Figure 8. Using the windscreen as emergency exit by cutting it.

The usability could be an important principle when reconsidering the EE-s in buses. But from regulatory point of view, the usability shall be a quantitative, measurable, objective term (objective as it can be). Of course there are many possibilities to do that, in the following one method will be shown and discussed.

POSSIBLE SPECIFICATION OF USABILITY

First of all a classification should be set up related to the usability of EE-s. The usability could be very good, good, acceptable, bad, very bad and unusable. This last category is clear, the EE is unusable if in the given accident situation the EE cannot be opened because the bus is laying on that side, where the EE is located. The technical aspects of the classification could be:

- Opening of the EE includes the following: to find the exit, to approach it, to understand its operation and to open it.
- Climbing up to EE when use it by a passenger
- Jumping down from EE (from the bus) when use it.
- Possibility of the continuous use by the passengers, following each other, considering children, elderly people and injured persons, too.

Table 1. summarizes the possible technical parameters of the usability. When proposing this specifications and figures, certain assumptions were used:

- Certain, but not well defined positive co-operation is presumed among the passengers when evacuating the bus.
- Certain, but not well defined outside help is presumed (but not organized, well trained help) e.g. given by the driver, or by one or two younger, stronger male passengers using first the EE, or by outside people being close to the accident.
- The assigned side-wall emergency windows may be used without the very negative effect of the sharp, pointed remaining parts of the broken window. This negative effect can be avoided by not using breakable side window as emergency exit (there are more technical solutions) or clean the window frame very carefully (it takes too much time) or cover the window frame by protective rag, see on Figure 1. (The problem is that generally the protective rag is not near at hand)

Table 1. Measures of usability

Usability Technical aspect	Very good	Good	Acceptable	Weak	Very weak	Unusable
Opening (1)	done by the driver	simple, easy, small effort by passenger	simple, small knowledge and effort by passenger	considerable effort and skill is needed by passenger	outside help is needed	In the given situation it is put out of action(3)
Climbing up to the exit when use it	no need	no need	less than [1 m]	more than [1 m]	more than [1,5 m]	
Jumping down from the exit when use it	no need	less than [1 m]	less than [1,8 m]	less than [1,8 m]	more than [1,8 m]	
Possibility of continues use (2)	possible, no obstacles, difficulties	possible with small help	possible with inner and outside help	possible with inside and outside help	not possible	

(1) opening includes: to find the exit, to understand its operation and to open it
(2) considering children, elderly passengers and injured persons, too, following each other in the evacuation
(3) e.g. when the bus is laying on that side where the exit is located

RESULTS OF EVACUATION TESTS

After preparing (1974) and putting into force (1976) the EE's requirements in R.107, some tests were made in different countries to check the usability of the EE-s. These test results were not compared, discussed and evaluated together and were forgotten by the passing time. Now some of them will be shown again.

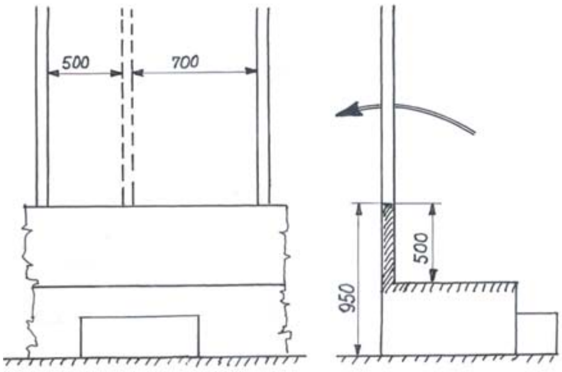


Figure 9. Evacuation test arrangement in Cranfield.

In UK, Cranfield Inst. Of Technology made a test with 100 voluntary elderly people (their average age was 73 years) to pass through a simulation of side emergency window [2] Figure 9. shows the test arrangement. They simulated 3 different width of the window (500 mm, 700 mm and 1200 mm) The main conclusion was surprising: 44% of the sample were unable to exit through the window simulation, they refused to make a trial. They did not find difference between the 500 mm and 700 mm width, but the 1200 mm shortened the exit time by 26%. They tested the required height of the window, it started from 950 mm up to 1400 mm above the waistrail. The average evacuation time for one passenger (who passed the test was 10 sec (500 mm width) and 7 sec (1200 width). It has to be mentioned, that the "geometry" of this test arrangement was not "realistic": the inside height of the waistrail is generally in the range of 600-800 mm (instead of 500 mm) and the outside height above the road is in the range of 1600-1800 mm (instead of 950 mm)

Another interesting evacuation test series from UK was made in the University of Technology, Loughborough [3]. They used existing coach (passenger capacity 53, floor height 1200 mm, waistrail height to the floor/road level 750/1860 mm) They tested the emergency window (hinged type) and emergency door (also hinged type) They reproduced and tested also the emergency door and window with the required minimum dimensions according to the regulation. (see Figure 10).

They performed the test with and without outside podium having a height above the ground 600 mm for the door and 1200 mm for the window. (see Figure 11.) They used three samples of passengers differing in age (Group1: 7-15 years; Group 2: 20-45 years; Group 3: 60-75 years) There were 48 persons in every group, 50% male/female. The tests with podium here are also not realistic. The different passenger motions are shown on Figure 11. and Figure 12. when there is, or there is no podium. The report contains a lot of test results, some interesting, characteristics results are given in Table 2, showing the evacuation time of 48 passengers..

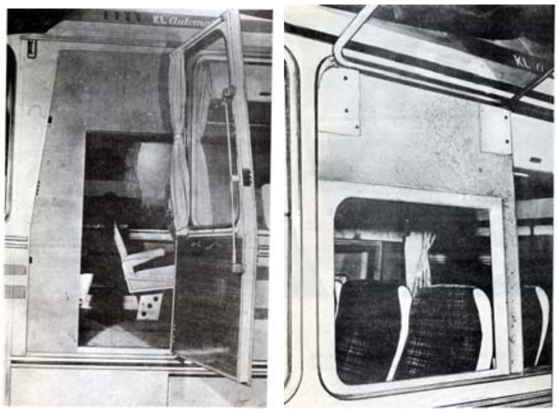


Figure 10. Normal and minimum size exits used in the Loughborough tests.

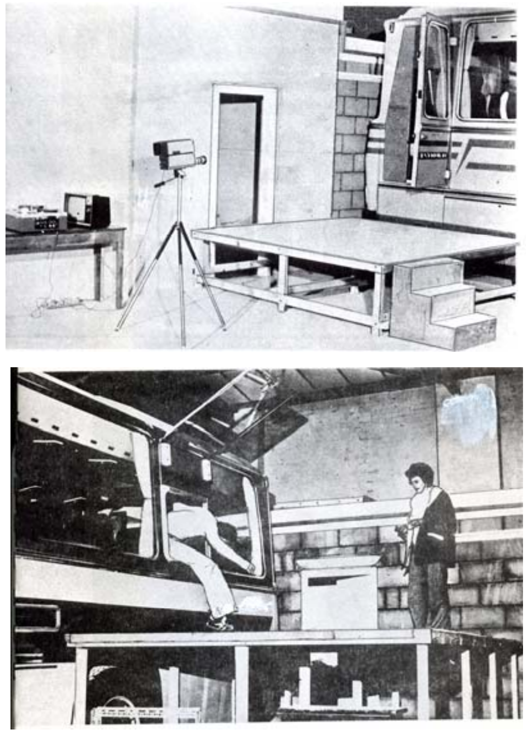


Figure 11. The tested versions of EE-s with outside podium..

Table 2. Evacuation times

Way of evacuation	Group 1	Group 2	Group 3
Emergency door with podium	120 sec	150 sec	240 sec
Emergency door without podium	210 sec	210 sec	*
Emergency window with podium	270 sec	330 sec	600 sec
Emergency window without podium	**	540 sec	**

* not all the passengers could make the test
** Group 1 and 3 could not perform this test

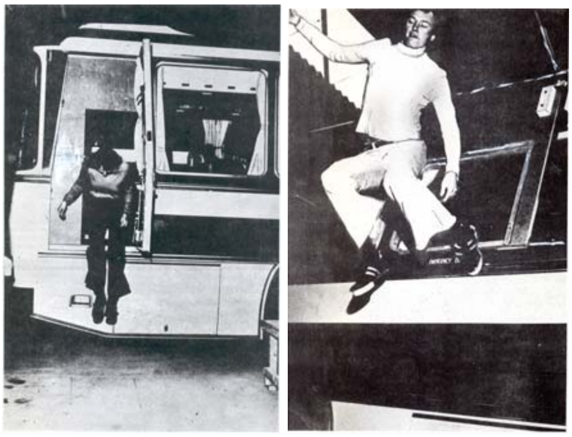


Figure 12. Leaving the bus without podium

The ratios between some interesting issues:

- Male/female in the same age group 1: (1,2-1,5)
- Faster 12/slower 12 passengers 1: (1,2-1,6)
- Emergency door/emergency window 1: (2,2-3,5)

There was a test series carried out in Germany, too [4]. Two scheduled service buses and two coaches were used in the evacuation test with two kind of passenger samples: children aged between 8-10 years and adults. The vehicles were standing on its wheels. When testing emergency windows, outside podiums were used. No details about the vehicle geometry and passenger capacity. The complete measured evacuation times are given in Table 3. (all the passengers leaving the bus) Two interesting statements from the document:

- The most dangerous accident situation is: the bus is burning while lying on its side.
- Possible increase of evacuation effectiveness needs at least two exit systems (instead of one) with increased capacity: when the vehicle is in standing position or lying on its side.

Table 3. Evacuation times

Way of evacuation	Service bus		Coach	
	children	adults	children	adults
2 service doors (SD) (1)	30 sec	30 sec	40 sec	30 sec
2 emergency windows (SW) (3)	-	52 sec	-	52 sec (2)
2 SD + 2 SW	-	15 esc	-	24 sec (4)

(1) 2/3 of the occupants used the rear service door
(2) Half of the groups left the vehicle
(3) Braking the window and cleaning an exit hole took 15 sec
(4) 2/3 of the occupants used the doors

We also made evacuation tests in Hungary, in the Research Institute AUTOKUT [1] The used coach had a passenger capacity of 45, floor height 940 mm, waistrail height above the road 1750 mm, 2 service doors (the rear one was transformed for emergency door, too.) Two groups of passengers were used: professional, trained firemen, age 20-40 and adult persons in age 25-45. (15 females and 30 males) The bus was standing on its wheels, the "passengers" knew what to do after the signal "fire", the firemen wore light uniform, and the adult persons wore summer clothes without hand baggage. The measured complete evacuation times are given in Table 4.

Table 4. Evacuation times

Way of evacuation	Passenger group	Number of tests	Evacuation time
Front service door	firemen	2	25-28
Front service door	adults	2	37-40
Real service door	adults	1	40
Two service doors	adults	1 Table II.	20
Rear emergency door	adults	1	54
Side emergency windows	firemen	1	10

In this last case the firemen kicked out – in the same moment – all the side windows together with the rubber mounting on both sides of the bus and jumped out trough the empty window frames, see Figure 13.

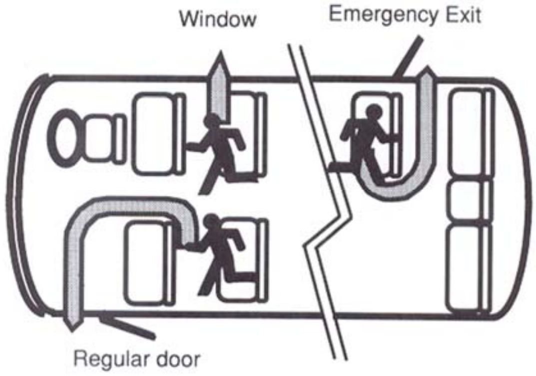
Figure 13. Evacuation tests in Hungary: service door and side window

Test was carried out with a 30 years female to break the window and leave the bus through the emergency window. The woman was afraid of climbing up and jumping through the window which had sharp glass fragments on the waistrail, therefore she needed help from outside. The measured times for one test:

- Finding and getting the hammer, cracking the glass: 15 sec
- Creating a "free exit" with appropriate size, additional: 25 sec
- Leaving the bus with outside help, additional: 50 sec

An interesting evacuation test series were carried out in Japan, JAMA [5]. They used a high deck coach and tested the use of service door, emergency door and emergency side window as EE. The passenger sample was built up from 6 schoolchildren (8-12 years) 12 adults (20-28 years) and 6 elderly people (66-73 years) Figure 14. shows the test bus and the three kinds of tests. The emergency window was not a breakable one, but sliding type. If the test passengers thought that it is dangerous to jump down to the ground either from the emergency door (floor height ≈ 1500 mm) or from the emergency window (waistrail height 2300 mm) they could use an outside podium (1500 mm high). They measured the evacuation time of every individual from starting the process (standing up from the seat) to the end (being outside, on the ground or on the podium). They repeated the test with every person three times. Some results:

- The evacuation time of one passenger is around 10 sec, no considerable difference between the age groups or between emergency door or window
- The evacuation time through service door is 7 sec for children and adults, and 10 sec again for elderly people.
- ¾ of the evacuation time was needed to find and get the EE, to understand its operation and to open it.
- At the first trial no one of the children and only half of the elderly people could perform the test with the emergency door. They could not open it.



50 sec

Figure 14. The coach used for evacuation tests in Japan

EVALUATION OF DIFFERENT EMERGENCY EXITS

Accepting the new assumptions:

- The usability of the same type of EE could be different in different accident situations and in different bus categories (or in the same category, too)
- The usability of the different types of EE are not equal in different accident situation
- The usability of one given EE could be different in different accident situations.

Table 5. The bus is standing on its wheels

Evacuation through	Large, single deck bus		Double deck bus		Small bus
	Low deck	High deck	Lower deck	Upper deck	
SD	very good	very good	very good	-	very good
ED	good	good	-	good	-
RD	-	-	-	-	good
SW	good	acceptable	good	very weak	good
RW	acceptable	weak	-	very weak	unusable
EH	very weak	very weak	-	very weak	acceptable
DD	weak	weak	weak	-	weak
WS	acceptable	acceptable	acceptable	very weak	-

The used symbols:

SD	service door	SW	side-wall emergency window
ED	emergency door	RW	rear-wall emergency window
RD	rear-wall door	EH	escape hatch
DD	driver's cab door	WS	windscreen

The different types of EE-s in different accident situations should be evaluated based on the specifications proposed in Table 1. Table 5. summarizes the usability of different EE-s when the bus is standing on its wheels. In case of large, single deck buses:

"low deck" means: waistrail height above the road is less than 1,8 m;

"high deck" means: waistrail height above the road is more than 1,8 m.

The upper deck of a DD vehicle is rather poor from the point of view of EE-s. May be the staircase communicating to the lower deck (to service doors) may be accepted as a "good" route, but only when the vehicle is in standing position.

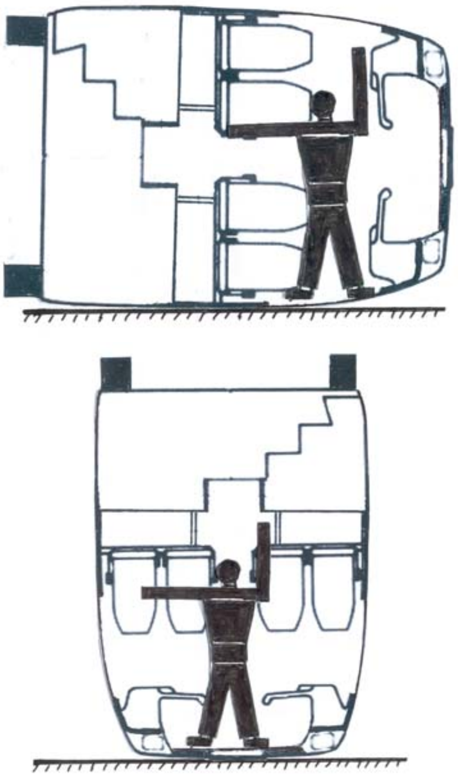


Figure15. The bus in different final positions.

Table 6. shows the situation when the bus is lying on its door side, while Table VII. the other side position. Figure 15. shows the bus in different final positions, lying on its side or on its roof. The sketches are scaled and the passenger contour represents an 1,7 m tall person, just to give an impression about the usability of different EE-s.

Table 6. Bus is lying on its door side

Evacua-tion through	Large, single deck bus		Double deck bus		Small bus
	Low deck	High deck	Lower deck	Upper deck	
SD	unusable	unusable	unusable	-	unusable
ED	very weak	very weak	-	very weak	-
RD	-	-	-	-	good
SW	very weak	very weak	very weak	very weak	acceptable
RW	good	good	-	good	-
EH	very good	very good	-	very good	good
DD	very weak	very weak	very weak	-	very weak
WS	very good	very good	very good	very good	-

Table 7. Bus is lying on the other side

Evacua-tion through	Large, single deck bus		Double deck bus		Small bus
	Low deck	High deck	Lower deck	Upper deck	
SD	weak	weak	weak	-	good
ED	unusable	unusable	-	unusable	-
RD	-	-	-	-	good
SW	very weak	very weak	very weak	very weak	acceptable
RW	good	good	-	good	-
EH	very good	very good	-	very good	good
DD	unusable	unusable	unusable	-	unusable
WS	very good	very good	very good	very good	-

Finally Table 8. shows the usability of different EE-s when the bus is standing on its roof. These four Tables (5 – 8) illustrate well the wide range of usability of the different EE-s in different vehicles and accident situations. For example the service door could be evaluated as "very good"; "good"; "weak"; or "unusable".

Table 8. Bus is standing on its roof

Evacuation through	Large, single deck bus		Double deck bus		Small bus
	Low deck	High deck	Lower deck	Upper deck	
SD	good	good	acceptable	-	very good
ED	good	good	-	good	-
RD	-	-	-	-	good
SW	good	good	good	good	good
RW	good	good	-	good	unusable
EH	unusable	unusable	-	unusable	unusable
DD	acceptable	acceptable	acceptable	-	weak
WS	very good	very good	-	very good	-

POSSIBLE SET UP OF NEW REQUIREMENTS

To determine the required number and location of EE-s the following should be considered:

- the passenger capacity of the bus (or the separated passenger compartments)
- possible major after-accident positions of the bus
- usability of different EE-s in different bus positions and in different bus categories
- limited time in case of fire.

From the bus fire tests it may be said that in case of fire the available time for successful evacuation is not more than 200-300 sec. The different evacuation tests showed that 45-48 passengers may leave the bus (when it is standing on its wheels, passengers in normal position, no panic, no injured passengers, everybody knows what to do)

- through one service door (very good usability) in 40-80 sec
- through the emergency door (good usability) in 60-210 sec
- through one emergency window (acceptable usability) in 360-900 sec

The proposed requirement for the minimum number and location of EE-s is the following:

a) every separated passenger compartment in every essential bus position (standing on its wheel or on its roof, lying on its sides = 4 positions) shall have:
   - up to 20 passengers min. 2 at least “acceptable” EE-s, among which 1 is “good” or “very good”
   - for 21-70 passengers min. 6, at least “acceptable” EE-s, among which min. 2 is “good” or “very good”
   - above 70 passengers, additionally two at least “acceptable” EE-s are required

b) above the required number of “good” or “very good” EE-s, every extra “good” or “very good” one shall be considered as two “acceptable” EE-s.

c) the staircase to the upper deck in DD vehicles or the joint section between the two parts of articulated vehicles may be connected as a “good” EE when the vehicle is standing on its wheels.

As an example, let us check a 12 m long tourist coach with 53 passenger capacity and waistrail height above the road 1,7 m and above the seat-floor 0,8 m. The coach has the following EE-s: 2 service doors; 1 emergency door; 3 escape hatches; 1 rear-wall emergency window; 2-2 side-wall emergency windows and 1 one windscreen.

The required number of EE-s is: minimum 6 “acceptable” EE-s among which at least 2 are “good” or “very good” in every essential bus position. Checking these positions, the results are shown in Table 9.:

Table 9. Evaluation of requirements

EE-s	Standing on the		Lying on the	
	wheels	roof	door side	other side
2 SD	very good	good	-	-
1 ED	good	good	-	-
4 SW	acceptable	good	-	-
1 RW	acceptable	good	good	good
3 EH	-	-	very good	very good
1 WS	acceptable	very good	good	acceptable*
good or very good	3	9	5	4
acceptable	6	2	-	1
requirements	met	met	met	met

* the driver’s cab should be considered

REMARKS

It is interesting to underline that the role of the emergency side windows is underrated, because they cannot be used in two and half accident situations, (the half is standing on its wheels but having high waistrail position). The breakable emergency windows may be omitted in the future, because there usability is questionable. In the same time the windscreen has high importance, because it can be used in every position and in three cases its usability is good or very good. (To equip the bus with a glass cutting device and skill the driver about its use is the required condition.)

The EE-s of DD vehicles shall be studied in detail. The lower deck is in vulnerable position when the bus is lying on its sides and the upper deck when it is standing on its wheels. These problems shall be solved in the future.

Finally one more interesting problem, which strongly belongs to the usability of EE-s. All EE-s shall be so designed and equipped with handles, handholds, grips and special devices which can help to the passengers in using the EE in all essential bus positions. The access to the EE-s in every position is also important, considering that the passengers could be in very difficult, strange position, when the bus is not standing on its wheels. [5] [6]

REFERENCES

[1] Bus fire and evacuation tests. Informal doc. on the 91st meeting of GRSG. No GRSG-91-10. (Presented by Hungary) 2006 Manuscript, UN-ECE, Geneva, secretariat of WP.29

[2] Investigation into the ability of elderly people in climbing out of simulated bus emergency exits. Project report, March, 1974. Industrial Ergonomics. Cranfield Institute of Technology. Manuscript. (Presented in GRSA)

[3] Emergency exits from public service vehicles. Institute for Consumer Ergonomics, University of Technology, Loughborough, Leicestershire. March, 1976. Study report, manuscript (presented in GRSA)

[4] Evacuation of bus passengers: emergency exit systems. TRANS/SC1/WP.29 /GRSA/R.105 December, 1985 (Presented by the Federal Republic of Germany)

[5] Yukio Shiosoka – Teekeshi Kuboike. Research on the evacuation readiness of bus crews

and passengers. Investigation of current bus exit performance and effect of easy-to-understand emergency exit display. 15th ESV conference, Melbourne 1996. Vol.2. p.1854-1860

[6]] Sharon Cook – Dean Southal. PSV emergency exits: passenger behaviour and exit design. ICE Ergonomics Ltd., Loughborough University, Leicestershire. September, 1996. Research report, ordered by DoT. Manuscript.